Quality-assured solutions for green roof gardens on concrete decks with zero tolerance for leaks

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Abstract

Eco neighborhoods with green infrastructure solutions are increasingly being prescribed today in Swedish cities for reducing and attenuating storm water runoff, increasing biodiversity, having a temperature moderating effect and for energy saving. Thus, contractors are simply required to build with green gardens on concrete decks, such as green roofs, green terraces, green courtyards and green complete neighborhoods. A lot of knowledge and experience is in fact lacking today, and consequences may therefore be devastating. If green system solutions are to be seen as an obvious choice in future settlements, and not as a problem, there must be clear guidelines and specifications that ensure a sustainable outcome. This is missing today. This paper reports a project aiming at bringing together researchers, government and industry to the collaborative development of new and attractive solutions for green roof gardens with consideration to the environment and high requirements for durability, materials, construction and energy efficiency. These solutions must also be adaptable to similar types of facilities, specific needs and environments. One such area concerns public land such as parks, streets and squares on concrete decks. Certification and tailored guidelines for different types of systems are being developed. The initiating part of this project clearly indicates that there is a need for better understanding, more research and long term monitoring/follow up of green roofs. Furthermore, a holistic approach is introduced to ensure that one good green roof function will not have severe negative effects on other functions.

Keywords: green roof garden, guidelines.

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1 Introduction

Sustainability is a difficult but vitally necessary goal for any city today. One example of many things that a sustainable city might implement is green roofs. Other examples concern solar panels, bike lanes, water recycling, centralized recycling facilities, reuse of building material, wind energy, etc. A sustainable city is supposed to be maintained for many centuries to come.

As an effort for sustainability, eco neighborhoods with green infrastructure solutions are increasingly being prescribed today in Swedish cities like Stockholm, Malmö and Gothenburg for reducing and attenuating storm water runoff, increase biodiversity, have a temperature moderating effect and for energy saving.

Contractors, thus simply are required to build with green establishments/gardens on concrete decks, such as green roofs, green terraces, green courtyards and green complete neighborhoods. A lot of knowledge, experience, standards and guidelines are in fact lacking today for this, and consequences may therefore be devastating [1]. In stressing on ecological benefits of green roofs, many proponents have ignored the importance of the underlying waterproofing system upon which the success or failure of the green roof construction system as a whole depends. Historical reasons for not implementing green roofs have been, their high cost, lack of engineered soils, difficulties in maintenance and waterproofing failure [2]. Assurances for long-term performance expectations for green roofs must be put in place, especially if they are required in city codes. Consequently, if green roofs are not also built successfully, considering that all parts of the green roof assembly should be compatible and work well together for a long time, green roofs will fail causing unnecessary costs, problems and suffering.

Existing literature is often limited to a certain part of the green roof construction system, such as the plant bed or the garden's design, storm water management, drainage or ecological benefits. Researchers understandably tend to focus on their own specialist field and thereby may forget or generalize other aspects [3]. Very little attention has still been given to the waterproofing system. Extensive research has been conducted primarily in Germany, Austria and Switzerland in the 1960–70s. The modern green roofs we have today can be linked mainly to this research. However, there is also a lot of information online from companies that supply and install products for green roofs. These companies often have their own different specifications, guidelines and recommendations.

Only a few countries have regulations and guidelines specifically for green roofs. The oldest regulations can be found in the German standard "Guideline for the Planning, Construction and Maintenance of Green-Roofing – Green Roofing Guideline", first published in 1984 [4]. The standard has since been published in a number of updated editions. It includes various types of green roofs, different vegetation types, requirements for construction, installation procedure and the operation and maintenance of green roofs. The standard refers to constructions in Central European climate with a focus on German building regulations. Neither Greece nor other Mediterranean countries have their own standards for green roof

installations [5], and Scandinavian countries like Sweden do not either. A best practice guide sets standards for green roof design and installation in the UK [6].

The goal of the project described in this paper is to develop a network and forum, for developing new guidelines and certification system for Scandinavian conditions. This work can in turn lead to and result in durable and attractive construction solutions in the international forefront of green roof systems and similar facilities with measurable impact on sustainability in terms of durability, health, environment, economy, security and social interaction. At normal maintenance, these solutions will have to run smoothly for 100 years. Identifying gaps between different technologies involved in green roof construction is an essential part of the work.

Figure 1: Climate-friendly green outdoor environment planned in Stockholm.

A green roof establishment on buildings or other structures must be carefully built up from the concrete deck, and be completely secured leak-proof. On top of the deck is therefore generally a waterproofing system that must protect the underlying building from moisture and water leakage. This normally includes a root barrier to prevent root penetration through the waterproofing layer. Thermal insulation is installed in combination with the waterproofing and root barrier, and then the garden/vegetated construction is installed on top, including draining layers and soil / plant substrate, often with a geotextile between.

1.1 Waterproofing system and insulation

For roof waterproofing systems in green roof construction, resistance to root penetration, mechanical and chemical effects/degradation, high loads, stress and aging are required. The system must exhibit good flexibility and workability as

well as a homogeneous and continuous waterproofing under different types of vegetation. The choice of system depends on the type of roof (with or without thermal insulation in the waterproofing system, slope, etc.), load (use, service and maintenance, irrigation system, equipment, possible redevelopment of the building, etc.) and vegetation type (extensive or intensive). It is important that planning work is done in close co-operation between architects, designers and performers, turnkey contract could be advantageous. The existence of product data sheets for evaluation is also central, as are proven methods of installation for details. Guarantees, certification and follow-up are important parameters in this context. There are no standards or guidelines concerning waterproofing systems specifically developed and suitable for green roofs of different kinds today. Waterproofing membranes under green roof systems must for instance resist fungus and bacteria in soils, acids, alkalis and other chemicals including those commonly contained in fertilizers [7].

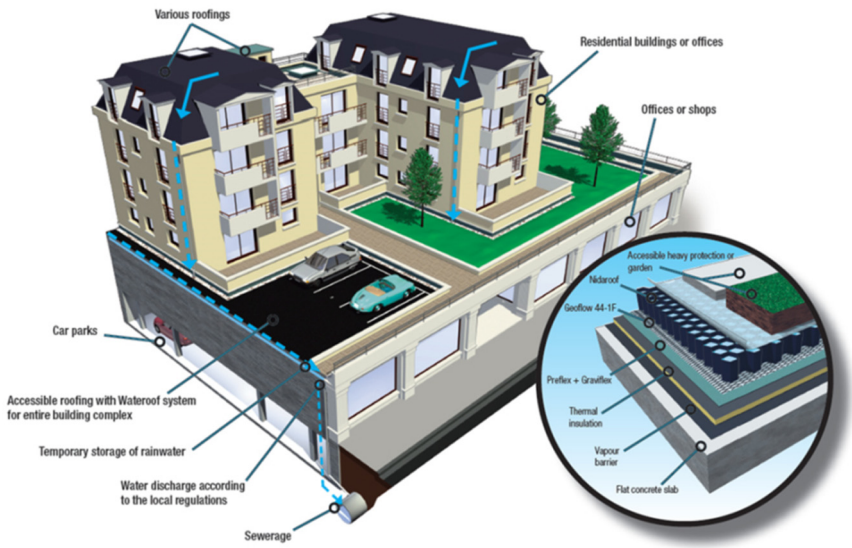

Figure 2: Example of waterproofing system from Icopal [8].

1.2 Plant bed and vegetation

The plant bed typically consists of a drainage layer and a layer of soil substrate, including the vegetation as well. To achieve sustainable systems, deeper knowledge about substrate quality and plant bed construction for different kinds of green roofs need to be developed. It includes knowledge about air and water holding capacity of different kinds of substrates and optimal depth for different performances. Selection of feasible plant materials for different types of green roofs is also needed. There are internationally recognized knowledge and

experience of several of the identified problem areas, but this must be made available and adjusted against the Swedish building standards and climate. Loads of vegetation and anchoring of trees at wind loads also need to be addressed.

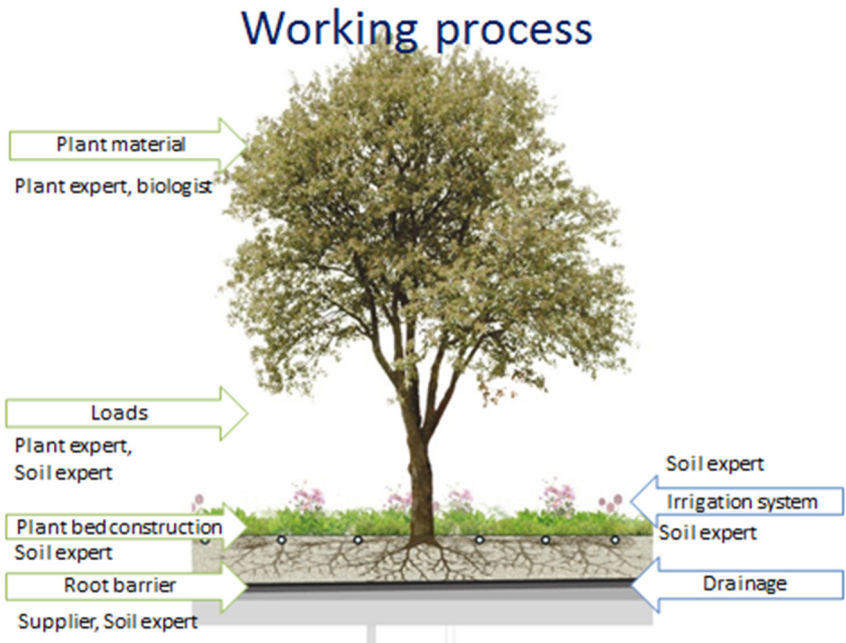

Figure 3: The working process (drawing by White and Sweco).

2 The project

Vinnova (Swedish Governmental Agency for Innovation Systems) is Sweden's innovation agency, working for sustainable growth and benefiting society [9]. Around SEK 2.7 billion SEK per year are invested in different by Vinnova identified areas. One such area is called Sustainable Attractive Cities – for new solutions within areas such as environment, energy, transport and community building. The project described in this paper is funded within that area by Vinnova, since 2013. The project is coordinated by Swedish Cement and Concrete Research Institute and will go on until at least August 2016.

The purpose of the project concerns research and development towards more sustainable cities in Sweden by the implementation of successfully constructed and maintained green roofs that will be assured for long term performance and leak-proof.

2.1 Initiating part of the project – Stage 1

A great need for developing new overall solutions for green roof garden systems was identified, taking into account the environment and high requirements concerning sustainability, material, construction techniques and energy efficiency. Problems with the system solutions used today, needs and possible new overall construction ideas have been identified and analysed mainly within a workshop involving participants from the public and private sector, industry and scientific researchers. Documentation from this workshop was included in the final report to Vinnova for this first initiating part of the project. Furthermore, a consortium or forum was established.

Not to have any leakage during the lifetime of the green roof garden is incredibly important but cannot currently be guaranteed. Some real estate companies are therefore trying to avoid these roofs because the risk is too great. This applies mainly to intensive green roofs. But city areas with intensive green roof solutions are ordered anyway in increasing quantities.

There is hardly any doubt that a green roof is environmentally beneficial, but to design, install and maintain such a facility is a complex challenge that requires great skill and experience. Obviously, green roofs are also more expensive to install than traditional roofs. Intensive roofs require intensive maintenance, irrigation and drainage systems and are limited by climatic conditions. They could be very expensive to repair, if leakage occurs. One could of course argue that there is always a certain risk of leakage for all roofs, and flat roofs in particular. However, the risk of leakage in green roofs is believed to be higher and the consequences much more severe and expensive compared to traditional roofs. As already mentioned, this applies especially for intensive green roof systems. According to The National Roofing Contractors Association (NRCA) in the US, up to 40% of flat roofs develop serious problems within one year of installation due to leakage, and leaky roofs cost American businesses billions of dollars annually. Testing for roof leaks is complicated, on existing roofing in particular, not to mention existing green roof installations.

Comments and suggestions from the workshop mentioned above are roughly quoted and summarized below, showing the opinion of the approximately 70 Swedish participants in this workshop concerning quality assured solutions for green roof gardens on concrete deck with zero tolerance for leaks. Beyond all doubt, damage due to leakage under the green roof installation was the main concern among participants. One might say that there was a clarion call for more technical knowledge and better guidance for safe and reliable performance of green roof construction. Comments and suggestions from the workshop:

- Forum for knowledge, experience and networking are missing. Interdisciplinary research and innovation is needed. Foreign knowledge and experience must be adapted to Nordic conditions.
- Different roles should be clarified and coordinated. Responsibilities must be clearly defined.
- What is the impact of future changes in the green roof installation? New solutions for change and repair must be planned from the start. What

opportunities and constraints exist? In-depth inventory of problems and identification of points of conflict are called for.
- Functional requirements and quality assurance are missing. Processes with checklists, systems assurance, fire rating, etc. are missing. New requirements should be identified.
- Operation and maintenance (management). Training packages must be developed. SGRI (Scandinavian Green Roof Institute) is underway with an e-course platform for green infrastructure. Trade associations should be involved.
- Knowledge of soil quality and substrate development needs to be produced on a larger scale. Maintenance of plants is an important area where regulations, advice and guidelines are lacking. Further research is called for.
- Requirements for waterproofing and waterproofing tightness are essential to avoid leakage. Further research is also needed here. Adjusted specifications and guidelines are lacking.
- Technical descriptions of how to efficiently install waterproofing, what type of drainage material that is desirable and how to install efficient substrate and vegetation are missing. One should look at the quality of the entire chain, from planning to waterproofing, substrate material, vegetation and subsequent maintenance.
- The client (representing for instance Stockholm City) wants to understand what he or she orders, and why, in order to feel secure. Relevant requirements should be developed and linked to follow-up activities (certification, verification). Large gaps are to be filled out. The added value of higher quality should also be highlighted and costs made visible. Contractors need backing up and assistance to procurement contracts. The client wants to buy a safe process by qualified/certified construction manager. This is not possible today.
- What does the value chain look like? Gaps need to be identified and addressed. Trial/research projects need to be identified and monitored. What lifetimes are actually built for today?

Based on results and findings of the limited Stage 1 project (May 2013–December 2013), and the great interest from public and private sector, industry and researchers, Vinnova decided to grant also the second project application concerning green roofs, i.e. project Stage 2, shortly described in the next section. The project can be continued in yet another stage, starting in 2017.

2.2 Next part of the project – Stage 2

New integrated solutions are being developed through collaboration in the forum created in the first part of the project, and hopefully will be put to use in future collaboration projects.

The research methods used in this investigation (including the initial Stage 1 project) are to first examine current standards and guidelines used for green roof installations, and sort it into distinct areas of knowledge and experience. Next, a review of these standards and guidelines, including procedures used for green roof

planning, installation and maintenance, is conducted for gap analysis. Finally, new standards and guidelines suited for Swedish building regulations and Swedish climate will be developed. Case studies are provided.

In this second part of the project, appropriate construction projects and buildings in Stockholm and Malmö are included. The selection of construction project has been done with respect to construction start (in 2015) and possible follow-up (in 2016). Selected roof garden cases so far are Hornslandet in Stockholm and Greenhouse in Augustenborg, Malmö.

Hornslandet is part of Norra Djurgårdsstaden, being one of Stockholm Environment profiled areas. The overall ecological objective is a climate and fossil fuel free district in 2030 where carbon dioxide emissions are less than 1.5 tons per person and year by 2020. The construction project includes some 150 apartments in houses with green roofs. Planning and installation are linked to the Stage 2 project. Input, analysis, evaluation, documentation and follow-up of the entire green roof construction system will be delivered by the project.

The Greenhouse construction project consists of three interconnected units: one fourteen-story building with about 34 apartments, twelve terraced houses and one eco-profile school building. On the roof of the fourteen-story building, there will be a rooftop garden with a large greenhouse for growing and social community. In particular, this roof garden will be linked to the Stage 2 project. As for Hornslandet: input, analysis, evaluation, documentation and follow-up of the entire green roof construction system will be delivered by the project.

Figure 4: Greenhouse, planned in Augustenborg, Malmö.

Furthermore, a green roof courtyard, covering an underground parking garage, is linked to the project. After some 50 years after construction, this courtyard has to be renovated due to severe leakage into the garage for a long time. The concrete

deck construction has been investigated and suitable measures have been proposed concerning concrete and waterproofing layer so far. Root penetration is likely the main cause for leakage. As for the two roof garden cases mentioned above: input, analysis, evaluation, documentation and follow-up will be delivered by the project.

Figure 5: Green roof courtyard causing leakage in the garage below ground.

For organizing the work into a suitable framework for the project, six work packages (WP) have been created. These packages address:

- Problem analysis and knowledge inventory.
- Waterproofing system, insulation and concrete deck.
- Plant bed and vegetation.
- Work process, from planning a green roof to maintenance.
- Standards, guidelines and certification.
- Coordination, administration, information, etc.

2.3 Participating partners and others

The city of Stockholm plans and builds construction facilities such as streets, plazas and parks on concrete deck, and therefore has great interest in the project. The city also imposes requirements on green features for buildings on city land, which constitutes about 80% of new construction projects in the city.

Stockholmshem is the nation's second largest housing company (with nearly 500 properties) owned by the city of Stockholm. They are responsible for Hornslandet (section 2.2).

MKB Fastighets AB has most green roofs of all housing companies in Malmö and probably most in the country. They are responsible for Greenhouse (section 2.2).

Participating partners, besides the above mentioned from the public sector (City of Stockholm, Stockholmshem and MKB), are CBI Swedish Cement and Concrete Research Institute, SP Technical Research Institute, SLU Swedish University of Agricultural, Sweco Environment, SGRI Green Roof Institute in Malmö and White Architects. From industry, both large and small consulting firms and suppliers of products and product solutions are included (Icopal, Sealeco, DAB Domiflex, Elmico, Build Smart, Röda Tråden, VegTech and Byggros) and several industry associations such as Rebet (concrete repair) and GAFS (Mastic Asphalt Association in Sweden). Among other participants in the network are KTH Royal Institute of Technology, Oscar Properties Construction, Familjebostäder, Ramböll, JM Construction, Grontmij, Drenera, Takcentrum Sweden, Nordic Waterproofing, BSO Gardening, Marbit and Svensk Byggtjänst. We anticipate that a large number of companies have joined the network and want to participate in any future collaborative projects.

3 Conclusions and work in progress

Green roof gardens are increasingly being prescribed in Swedish cities, and construction companies simply are required to build with green gardens on concrete decks. However, there is a lack of knowledge, experience, standards and guidelines as well as collaboration between parties when installing such systems. Not to have any leakage during the lifetime of a green roof garden is incredibly important but cannot be guaranteed today. Green roofs can be very expensive to repair, if leakage occurs.

3.1 Stage 1

From Stage 1 of the project, the following conclusions can be drawn:

- Damage due to leakage under the green roof installation is the main concern according to representatives from public and private sector, industry and researchers in Sweden.
- There is a call for more technical knowledge and better guidance for safe and reliable performance of green roof constructions.
- There is a great need for developing new overall solutions for green roof garden systems.
- Identifying gaps between different technologies involved in green roof construction is essential.
- Forums for knowledge, experience and networking are missing.
- Certification, tailored guidelines and specifications for different types of systems need to be developed.

Conclusions mainly concern problems and needs identified by the new network forum created in this first part of the project, and the outcome of a workshop arranged in 2013 by project partners.

3.2 Stage 2

Stage 2 of the project is now focusing on comprehensive solutions in the light of all input from the initialization process.

Current standards and guidelines used for green roof installations are analyzed and sorted into distinct areas of knowledge and experience. A review of these standards and guidelines, including procedures used for green roof planning, installation and maintenance, is conducted for gap analysis.

Selection of construction projects has been done, starting in late 2014. Selected roof garden cases so far are Hornslandet in Stockholm and Greenhouse in Augustenborg, Malmö. Input, analysis, evaluation, documentation and follow-up of the entire green roof construction system will be delivered by the Stage 2 project. Furthermore, at least one green roof courtyard, covering an underground parking garage with severe leaking problems, is linked to the project.

This second part of the project includes six work packages. In different ways and in close collaboration, they will identify and develop relevant comprehensive solutions including new Swedish standards and guidelines for the future.

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